PATENT

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Applicant	:	Hiroyuki Nakata et al.
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CERTIFICATE OF CORRECTION TRANSMITTAL LETTER

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Sir:

A Certificate of Correction under 35 U.S.C. 254 is hereby requested to correct Patent Office printing errors in the above-identified patent. Enclosed herewith is a proposed Certificate of Correction (Form No. PTO-1050) for consideration. Also enclosed is documentation in support of this request.

It is requested that the Certificate of Correction be completed and mailed at an early date to the undersigned attorney of record. The proposed corrections are obvious ones and do not in any way change the sense of the application.

We understand that a check is not required since the errors were on the part of the Patent and Trademark Office in printing the patent.

Respectfully submitted,
PEARNE & GORDON LLP

By: /jeffrey j sopko/

Jeffrey J. Sopko, Reg. No. 27676

1801 East 9th Street, Suite 1200
Cleveland, OH 44114
(216) 579-1700

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αcom 33 of the position command comes to predetermined acceleration threshold αth 38 or less, the collision detecting threshold τvth 35 is not returned to the collision detecting threshold τth adjusted in the usual operation, but the collision detecting threshold τvth 35 may be kept $\tau th + d\tau th$ for the predetermined time Td 37 as shown in Fig. 21.

This example will be described with reference to Fig. 21. In Fig. 21, for a period of the time 0.6 to the time 0.8 when the torch pull-up operation is being performed, the absolute value of the acceleration component αcom 33 of the position command exceeds the predetermined acceleration threshold αth 38. Therefore, for this period, the collision detecting threshold τvth 35 becomes greater by $d\tau th$ 36 than that in the usual case as shown in the Numerical Expression 6. When the absolute value of the acceleration component αcom 33 of the position command becomes higher than the predetermined acceleration threshold αth 38 once, and next becomes lower (at the time 0.8 in Fig. 21), the collision detecting threshold τvth 35 is kept $\tau th + d\tau th$ for the predetermined time Td 37.

Thus, even in case that the absolute value of the acceleration component αcom 33 of the position command exceeds the predetermined acceleration threshold αth 38 and thereafter becomes lower than the acceleration threshold αth 38, the value of the collision detecting threshold τvth 35 is not returned to the collision detecting threshold τth immediately, but is kept $\tau th + d\tau th$ for the predetermined time Td 37. Hereby, it is possible to prevent the erroneous detection of collision even in case that delay in phase by the vibration due to the spring component of the reduction gear and the continuous vibration are produced.

Further, the processing of keeping the value of the collision detecting threshold τvth at $35\tau th + d\tau th$ for the predetermined time Td 37 is performed by, for example, a program stored in CPU (Central Processing Unit) provided in the robot system.

Further, the embodiment has been described on the basis on the kinetic calculation method. However, the method in the embodiment can be applied also to the disturbance estimating observer shown in Fig. 18

As described above, in case that the welding torch pulling-up operation that is larger than the usual operation in acceleration component is performed, the collision detecting threshold is made greater than the threshold adjusted in the usual operation, whereby the erroneous detection of collision can be prevented. Further, in case that the

$d\tau th$ is an increase of the threshold corresponding to spring vibration of the reduction gear.

Further, the above τth is previously found on the basis of the usual operation executed actually, and the $d\tau th$ is previously found on the basis of the unusual operation executed actually.

Fig. 20 shows a waveform when the collision judgment has been performed in a collision judging block 31 by means of this collision detecting threshold τvth 35. In Fig. 20, as an example of the unusual operation, a welding torch pulling-up operation by a robot is shown.

As shown in Fig. 20, for a period of the time 0.6 to the time 0.8 when the torch pull-up operation is being performed, the absolute value of the acceleration component αcom 33 of the position command exceeds a predetermined acceleration threshold αth 38. Therefore, for this period, as shown by the Numerical Expression 11, the collision detecting threshold τvth 35 becomes greater by $d\tau th$ 36 than the collision detecting threshold τth adjusted in the usual operation. Hereby, even in case that the vibration error of the reduction gear spring is added to the collision torque estimation value $\tau diso$ 28 in the period of the time 0.6 to the time 0.8, its absolute value does not exceed the collision detecting threshold τvth 35. Therefore, the erroneous detection of collision is not generated.

Further, after the time 0.8, the absolute value of the acceleration component αcom 33 of the position command comes to the predetermined acceleration threshold αth 38 or less. Therefore, the collision detecting threshold τvth 35 returns to the collision detecting threshold τth adjusted in the usual operation, whereby the collision detecting sensibility in the usual operation time does not lower.

The judgment of the above threshold and the change of the same are performed by, for example, a program stored in CPU (Central Processing Unit) included in a robot system.

In the above description, the example in which the collision detecting threshold τvth 35 is returned to the collision detecting threshold τth adjusted in the usual operation immediately when the absolute value of the acceleration component αcom 33 of the position command comes to predetermined acceleration threshold αth 38 or less has been indicated. However, immediately when the absolute value of the acceleration component

$\tau\mu$ 15 : Kinetic friction torque

τdyn 14 : Kinetic torque (sum of gravitational torque, inertial force, centrifugal force and Coriolis force)

τdis 16 : Collision torque

Further, the above-indicated kinetic friction torque $\tau\ \mu$ 15 can be calculated by the following Numerical Expression 7.

[Numerical Expression 7]

$$\tau\mu = K\mu \times sgn,$$

wherein $K\mu$ is the magnitude of kinetic friction, and

$$sgn = \begin{cases} 1 & (\omega m>0) \\ 0 & (\omega m=0) \\ -1 & (\omega m<0) \end{cases}$$

Further, the collision torque τdis on the right side of the Numerical Expression 6-2 can be obtained by the following Numerical Expression 8 which is modified on the basis of the Numerical Expression 6-1 and the Numerical Expression 6-2.

[Numerical Expression 8]

$$\tau dis = (Kt \times Im - Jm \times \alpha m - D \times \varpi m - K\mu \times sgn) - \tau dyn$$

In the above Numerical Expression 8, $Kt \times Im - Jm \times \alpha m - D \times \varpi m - K\mu \times sgn$ is torque outputted to the reduction gear by the motor, and τdyn is kinetic torque.

In Fig. 14, a reference numeral 30 represents the Numerical Expression 8 as a collision torque estimation block.

In the collision torque estimation block 30, a kinetic torque estimation value $\tau dyno$ 29 can be obtained by executing the inverse kinetic calculation in a kinetic torque calculation block 26 by means of motor velocity feedback of all shafts constituting the robot and mechanical parameters of the robot. The collision torque estimation block 30 finds a collision torque estimation value $\tau diso$ 28 by means of this kinetic torque estimation value $\tau dyno$ 29, and outputs this collision torque estimation value $\tau diso$ 28 to a collision judging block 31.

The collision judging block 31 detects collision, by means of a predetermined collision detecting threshold τth, in accordance with the following Numerical Expression 9.

described before. Therefore, it is not possible to perform the pull-up operation in advance in anticipation of the follow-up delay.

Therefore, in order to lessen the pressing amount of the welding wire 1, it is necessary to lessen the follow-up delay of the torch velocity TV. Further, in the welding process in the embodiment, the operating direction of the welding torch 4 from the position at the time TS0 is only the direction separating from the base material 7, which is different from the case in the conventional example in which the welding torch 104 moves also to the base material 107 side from the position at the time TS0' as described referring to Fig. 5. Therefore, there is no anxiety of buckling as indicated in the conventional example due to the vibration caused by the change of the velocity direction.

Further, it is preferable that the resultant velocity of the welding torch 4 velocity and the welding wire 1 velocity is constant. Therefore, it is good to adjust the velocity follow-up error so as to be minimized.

On the other hand, regarding the usual operation and positioning of the robot manipulator 9, the welding torch 4 located in a retreat position at the time TS0 in order to supply the base material 7 is moved in a weld start position by driving the robot manipulator 9 by the robot controller 10.

At this time, it is preferable that the leading end of the welding wire 1 stops without overshooting to the base material 7 side. This is because there is fear that the overshoot of the leading end of the welding wire 1 will cause the contact of the leading end of the welding wire 1 with the base material 7 at the unintentional point of time.

However, since the movement of the welding torch 4 in the welding direction after the TS4requires locus accuracy, that is, follow-up characteristic, it is preferable to increase the FF gain within an allowable value of the overshoot.

Next, a position control loop in the embodiment, which is constructed in the robot controller 10, will be described.

Fig. 1 is a block diagram showing a position control loop constructed in the robot controller 10. In Fig. 1, the same components as those in Figs. 6 and 9 are denoted by the same reference numerals.

The position control loop shown in Fig. 1 is constructed by adding, to the position control loop in the conventional example described referring to Fig. 9, a torch separation control block 224 for improving responsibility of only the torch pull-up operation in the arc